DNA MOLECULES ENCODING IMIDAZOLINE RECEPTIVE POLYPEPTIDES AND POLYPEPTIDES ENCODED THEREBY

REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of application Serial No. 08/650,766 filed May 20, 1996, which is related to provisional application Serial No. 60/12,600, filed March 1, 1996.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to DNA molecules encoding imidazoline receptive polypeptides, preferably encoding human imidazoline receptive polypeptides, that can be used as an imidazoline receptor (abbreviated IR). In addition, transcript(s) and protein sequences are predicted from the DNA clones. The invention is also directed to a genomic DNA clone designated as JEP-1A. The cDNA clones according to the invention comprise cDNA homologous to portion(s) of this genomic clone; including 5A-1 cDNA, cloned by the inventors that established the open-reading frame for translation of mRNA from the gene, and established the immunoreactive properties of its polypeptide sequence in an expression systems. Also, the invention relates to cDNA clone EST04033, which is another clone identified to contain cDNA sequences from the JEP-1A gene, and of which the 5A-1 is a part, that encodes an active fragment of the IR polypeptide in transfection assays, and the protein sequences thereof. The

invention also relates to methods for producing such genomic and cDNA clones, methods for expressing the IR protein and fragments, and uses thereof.

2. Description of Related Art

It is believed that brainstem imidazoline receptors possess binding site(s) for therapeutically relevant imidazoline compounds, such as clonidine and idazoxan. These drugs represent the first generation of ligands discovered for the binding site(s) of imidazoline receptors. However, clonidine and idazoxan were developed based on their high affinity for α_2-adrenergic receptors. Second generation ligands, such as moxonidine, possess somewhat improved selectivity for IR over α_2-adrenergic receptors, but more selective compounds for IR are needed.

An imidazoline receptor clone is of particular interest because of its potential utility in identifying novel pharmaceutical agents having greater potency and/or more selectivity than currently available ligands have for imidazoline receptors. Recent technological advances permit pharmaceutical companies to use combinatorial chemistry techniques to rapidly screen a cloned receptor for ligands (drugs) binding thereto. Thus, a cloned imidazoline receptor would be of significant value to a drug discovery program.

Until now, the molecular nature of imidazoline receptors remains unknown. For instance, no amino acid sequence data for a novel IR, e.g., by N-terminal sequencing, has been reported.

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Three different techniques have been described in the literature by three different laboratories to visualize imidazoline-selective binding proteins (imidazoline receptor candidates) using gel electrophoresis. Some important consistencies have emerged from these results despite the diversity of the techniques employed. On the other hand, multiple protein bands have been identified, which suggests heterogeneity amongst imidazoline receptors. These reports are discussed below.

Some of the abbreviations used hereinbelow, have the following meanings:

α_2AR	Alpha-2 adrenoceptor
BAC	Bovine adrenal chromaffin
ECL	Enhanced chemiluminescence (protein detection procedure)
EST	Expressed Sequence Tag (a one-pass cDNA documentation without identification)
I-site	Any imidazoline-receptive binding site (e.g., encoded on IR)
IR_1	Imidazoline receptor subtype$_1$
IR-Ab	Imidazoline receptor antibody
I_2Site	Imidazoline binding subtype$_2$
kDa	Kilodaltons (molecular size)
MAO	monoamine oxidase
MW	molecular weight
NRL	European abbreviation for RVLM (see below)
PC-12	Phaeochromocytoma-12 cells
^{125}PIC	[^{125}I]p-iodoclonidine
PKC	Protein Kinase C
RVLM	Rostral Ventrolateral Medulla in brainstem
SDS	sodium dodecyl sulfate gel electrophoresis

Reis et al. [Wang et al., Mol. Pharm., 42: 792-801 (1992); Wang et al., Mol. Pharm., 43: 509-515 (1993)] were the first to characterize an imidazoline-selective binding protein and to demonstrate it as having MW = 70 kDa. This was accomplished using bovine cells (BAC), which lack an α_2AR [Powis & Baker, Mol.

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Pharm., 29:134-141 (1986)]. The 70 kDa imidazoline-selective protein in those studies had high affinities for both idazoxan and p-aminoclonidine affinity chromatography columns and was eluted by another imidazoline compound (phentolamine). Unfortunately, those investigators failed to isolate sufficient 70 kDa protein to determine its other biochemical properties. To date, no one has reported the complete purification of an imidazoline receptor protein. Likewise, no amino acid sequences have been reported for IR.

Their 70 kDa protein was used by Reis and co-workers to raise "I-site binding antiserum", designated herein as Reis antiserum. The term "I-site" refers to the imidazoline binding site, presumably defined within the imidazoline receptor protein. Reis antiserum was prepared by injecting the purified protein into rabbits [Wang et al, 1992]. The first immunization was done subcutaneously with the protein antigen (10 μg) emulsified in an equal volume of complete Freund's adjuvant, and the next three booster shots were given at 15-day intervals with incomplete Freund's adjuvant. The polyclonal antiserum has been mostly characterized by immunoblotting, but radioimmunoassays (RIA) and/or conjugated assay procedures, i.e., ELISA assays, are also conceivable [see "Radioimmunoassay of Gut Regulatory Peptides: Methods in Laboratory Medicine," Vol. 2, chapters 1 and 2, Praeger Scientific Press, 1982].

The present inventors and others [Escriba et al., Neurosci. Lett. 178: 81-84 (1994)] have characterized the Reis antiserum in

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several respects. For instance, the present inventors have discovered that human platelet immunoreactivity with Reis antiserum is mainly confined to a single protein band of MW ≈ 33 kDa, although a trace band at ≈ 85 kDa was also observed. The ≈ 33 and ≈ 85 kDa bands were enriched in plasma membrane fractions as expected for an imidazoline receptor. Furthermore, the intensity of the ≈ 33 kDa band was found to be positively correlated with non-adrenergic ^{125}PIC Bmax values at platelet IR_1 sites in samples from the same subjects, with an almost one-to-one slope factor. In addition, the nonadrenergic ^{125}PIC binding sites on platelets were discovered by the present inventors to have the same rank order of affinities as IR_1 binding sites in brainstem [Piletz and Sletten, J.Pharm. & Exper. Therap., 267: 1493-1502 (1993)]. The platelet ≈ 33 kDa band may also be a product of a larger protein, since in human megakaryoblastoma cells, which are capable of forming platelets in tissue cultures, an ≈ 85 kDa immunoreactive band was found to predominate.

Immunoreactivity with Reis antiserum does not appear to be directed against human α_2AR and/or MAO A/B. This is a significant point because α_2AR and MAO A/B have previously been cloned and also bind to imidazolines. The present inventors have obtained selective antibodies and recombinant preparations for α_2AR and MAO A/B, and these proteins do not correspond to the ≈ 33, 70, or 85 kDa putative IR_1 bands. Thus, there is substantial evidence that, at least in human platelets, the Reis antiserum is

IR_1 selective.

Another antiserum was raised by Drs. Dontenwill and Bousquet in France [Greney et al., Europ. J. Pharmacol., 265: R1-R2 (1994); Greney et al., Neurochem. Int., 25: 183-191 (1994); Bennai et al., Annals NY Acad. Sci., 763:140-148 (1995)] against polyclonal antibodies for idazoxan (designated Dontenwill antiserum). This anti-idiotypic antiserum inhibits ^{3}H-clonidine but not ^{3}H-rauwolscine (α_2-selective) binding sites in the brainstem, suggesting it also interacts with IR_1 [Bennai et al., 1995]. As shown in Fig. 1, human RVLM (same as NRL) membrane fractions displayed bands of ≈ 41 and 44 kDa, as detected by the present inventors using this anti-idiotypic antiserum.

The present inventors have found that the bands of MW ≈ 41 and 44 kDa detected by Dontenwill antiserum may be derived from an ≈ 85 kDa precursor protein, similar to that occurring in platelet precursor cells. An 85 kDa immunoreactive protein is obtained in fresh rat brain membranes only when a cocktail of 11 protease inhibitors is used. Also, as shown in Fig. 1, it is found that Reis antiserum detects the ≈ 41 and 44 kDa bands in human brain when fewer protease inhibitors are used. Additionally, the Dontenwill antiserum weakly detects a platelet ≈ 33 kDa band. Thus, the present inventors have hypothesized that the ≈ 41 and 44 kDa immunoreactive proteins may be alternative breakdown products of an ≈ 85 kDa protein, as opposed to the platelet ≈ 33 kDa breakdown product.

In summary, the main conclusion from the above results is

that, despite vastly different origins, the Reis and Dontenwill antisera both detect identical bands in human platelets, RVLM, and hippocampus.

Using yet another technique, a photoaffinity imidazoline ligand, ^{125}AZIPI, has also been developed to preferentially label I_2-imidazoline binding sites [Lanier et al., J.Biol.Chem., 268: 16047-16051 (1993)]. The ^{125}AZIPI photoaffinity ligand was used to visualize ≈ 55 kDa and ≈ 61 kDa binding proteins from rat liver and brain. It is believed that the ≈ 61 kDa protein is probably MAO, in agreement with other findings [Tesson et al., J.Biol.Chem., 270: 9856-9861 (1995)] showing that MAO proteins bind certain imidazoline compounds. The different molecular weights between these bands and those detected immunologically by the present inventors is one of many pieces of evidence that distinguishes IR_1 from I_2 sites.

To the inventors' knowledge and as described herein, we are first to clone the gene, cDNAs and fragments thereof encoding a protein with the immunological and ligand binding properties expected of an IR. On this basis, we are first to identify the nucleotide sequences of DNA molecules encoding an imidazoline receptor and active fragments thereof, and the first to determine the amino acid sequence of an imidazoline receptor and active fragments thereof. The polypeptides described herein are clearly distinct from α_2AR or MAO A/B proteins.

SUMMARY OF THE INVENTION

The present invention involves various cDNA clones (ie., 5A-1 and EST04033) and a genomic clone (JEP-1A) which are directed to an isolated polypeptide(s) that is receptive to (bind to) imidazoline compound(s), and can be used to identify other compounds of interest. Currently available imidazoline compounds in this context are p-iodoclonidine and moxonidine. Initially, the inventors detected a polypeptide expressed by their cDNA clone (5A-1 isolated from a human hippocampus cDNA library) that immunoreacted with Reis antiserum and/or Dontenwill antiserum. The DNA sequence of the 5A-1 clone is encapsulated within a portion of the other clones (EST04033 and JEP-1A genomic clone).

In one aspect of the invention, a polypeptide includes a 651 amino acid sequence as shown in SEQ ID No. 5. This polypeptide is predicted from non-plasmid cDNA in EST04033; a clone which the inventors showed possesses sequences inclusive of 5A-1. Furthermore, transfection of EST04033 into COS cells yielded imidazoline receptivity by radioligand binding assays (described in detail later). Other imidazoline receptive proteins homologous to this polypeptide are also contemplated. Such polypeptide(s) generally have a molecular weight of about 50 to 80 kDa. More particularly, one can have a molecular weight of about 70 kDa.

In another aspect of this invention, a polypeptide includes a 390 amino acid sequence as shown in SEQ ID No. 6. This represents the polypeptide predicted from the non-plasmid DNA of

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the original 5A-1 clone. Such a polypeptide generally has a molecular weight of about 35 to 50 kDa. More particularly, it can have a molecular weight of about 43 kDa.

DNA molecules encoding aforementioned imidazoline-receptive polypeptide(s) are also contemplated. Such a DNA molecule, e.g., a cDNA derived from mRNA, can contain a nucleotide sequence encoding the 651 amino acid sequence shown in SEQ ID No. 5. Thus, a DNA molecule containing the 1954 base pairs (b.p.) (1954 b.p. encodes 651 amino acids) nucleotide sequence shown in SEQ ID No. 2 is contemplated. This represents the coding sequence for the polypeptide predicted by EST04033 transfections. In another embodiment, a DNA molecule includes the longer nucleotide sequence shown in SEQ ID No. 3. This represents the cDNA predicted to have been translated + not predicted to have been translated in transfections experiments of EST04033.

In another embodiment of the invention, a DNA molecule contains a nucleic acid sequence encoding the amino acid sequence shown in SEQ ID No. 6. In another aspect, it can include the 1171 b.p. nucleic acid sequence shown in SEQ ID No. 4. The 1171 b.p. nucleic acid sequence shown in SEQ ID No. 4 is the 5A-1 non-plasmid DNA.

The nucleic acid sequence of the genomic clone encoding the imidazoline receptor is further shown in SEQ ID No. 21. The nucleic acid and amino acid sequence of the predicted transcript (ie., cDNA) can be predicted from the description hereinbelow. The polypeptide encoded by the genomic DNA is shown in SEQ ID No.

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Sequence similarity with the sequences indicated in SEQ ID protocols of the attached Sequence Listing is defined in connection with the present invention as a very close structural relationship of the relevant sequences with the sequences indicated in the respective SEQ ID protocols. To determine the sequence similarity, in each case the structurally mutually corresponding sections of the sequence of the SEQ ID protocol and of the sequence to be compared therewith are superimposed in such a way that the structural correspondence between the sequences is a maximum, account being taken of differences caused by deletion or insertion of individual sequence members (DNA-codon or amino acid respectively), and being compensated by appropriate shifts in sections of the sequences. The sequence similarity in % results from the number of sequence members which now correspond to one another in the sequences ("homologous positions") relative to the total number of members contained in the sequences of the SEQ ID protocols. Differences in the sequences may be caused by variation, insertion or deletion of sequence members. Additionally in DNA sequences, different DNA-codons encoding for the same amino acid are considered identical in the context of the present invention. For amino acid sequences, conservative amino acid substitutions encoded by their corresponding DNA-codons, as well as naturally occurring homologs of the sequences, are considered within the context of sequence similarity.

DNA molecules of substantial homology (≥ 75 %) are an

implicit aspect of this sort of invention. As will be discussed later, the inventors have already identified two possible splice variants in the amino acid coding sequence. In addition, artificially mutated receptor cDNA molecules can be routinely constructed by methods such as site-directed polymerase chain reaction-mediated mutagenesis [Nelson and Long, Anal. Biochem. 180: 147-151 (1989)]. It is commonly appreciated that highly homologous mutants frequently mimic their natural receptor. A study by Kjelsberg et al. [J. Biol. Chem. 267: 1430-1433 (1992)] showed that all 20 amino acid substitutions produce an active receptor at a single site in the α_{1b}-adrenergic receptor. RNA molecules of ≥ 75 % complementarity to an instant DNA molecule, e.g., an mRNA molecule (sense) or a complementary cRNA molecule (antisense), are a further aspect of the invention.

A further aspect of the invention is for a recombinant vector, as well as a host cell transfected with the recombinant vector, wherein the recombinant vector contains at least one of the nucleotide sequences shown in SEQ ID Nos. 1-4, or sequences predicted by the genomic clone, or nucleotide sequences ≥ 75 % homologous thereto.

A method of producing an imidazoline receptor protein is another aspect of the invention. Such a method entails transfecting a host cell with an aforementioned vector, and culturing the transfected host cell in a culture medium to generate the imidazoline receptor.

A method for producing homologous imidazoline receptor

proteins, and the proteins produced thereby, are also considered an aspect of this invention.

A significant further aspect of the invention is a method of screening for a ligand that binds to an imidazoline receptor. Such a method can comprise culturing an above-mentioned transfected cell in a culture medium to express imidazoline receptor proteins, followed by contacting the proteins with a labelled ligand for the imidazoline receptor under conditions effective to bind the labelled ligand thereto. The imidazoline receptor proteins can then be contacted with a candidate ligand, and any displacement of the labelled ligand from the proteins can be detected. Displacement of labelled ligand signifies that the candidate ligand is a ligand for the imidazoline receptor. These steps could be performed on intact host cells, or on proteins isolated from the cell membranes of the host cells.

The invention will now be described in more detail with reference to specific examples.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 depicts a comparison of Reis antiserum (lane 1, 1:2000 dilution) and Dontenwill antiserum (lane 2, 1:5000 dilution) immunoreactivities for human NRL (same as RVLM) and hippocampus, as discussed in Example 1.

Fig. 2 depicts a comparison of Reis antiserum (1:15,000 dilution) and Dontenwill antiserum (1:20,000 dilution) immunoreactivities for plaques isolated from the human

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hippocampal cDNA library used in cloning as discussed in Example 2. The plaques contain the initial clone, designated herein as 5A-1, in a third stage of purification.

Fig. 3 depicts the restriction map of the EST04033 cDNA clone.

Fig. 4 depicts a competitive binding assay between ^{125}I-labelled p-iodoclonidine (PIC) and various ligands for the imidazoline receptor on membranes expressed in COS cells transfected with the EST04033 cDNA clone, as discussed in Example 4.

Fig. 5 depicts the prediction of introns and exons of the genomic clone (as analyzed by the GENESCAN program and verified by the available CDNAS).

Fig. 6 depicts the distribution of MRNA homologous to our CDNA in human adult tissues (bar graph) and the two species of MRNA (6 and 9.5 kb).

DETAILED DESCRIPTION OF THE INVENTION

The present invention is concerned with multiple aspects of an imidazoline receptor protein, and DNA molecules encoding the same, and fragments thereof, which have now been discovered.

First, a polypeptide having imidazoline binding activity has been identified, which contains the putative active site for binding, as discussed hereinafter. Although polypeptide(s) described herein has a binding affinity for an imidazoline compound, it may also have an enzymatic activity, such as do

catalytic antibodies and ribozymes. In fact, one such domain within our protein predicts a cytochrome p450 activity (described later).

Exemplary "binding" polypeptides are those containing either of the amino acid sequences shown in SEQ ID Nos. 5 or 6 (with the amino acid sequence predicted by EST04033 given in SEQ ID No. 5). Functionally equivalent polypeptides are also contemplated, such as those having a high degree of homology with such aforementioned polypeptides, particularly when they contain the Glu-Asp-rich region described hereinafter which we believe may define an active imidazoline binding site.

A polypeptide of the invention can be formed by direct chemical synthesis on a solid support using the carbodiimide method [R. Merrifield, JACS, 85: 2143 (1963)]. Alternatively, and preferably, an instant polypeptide can be produced by a recombinant DNA technique as described herein and elsewhere [e.g., U.S. Patent No. 4,740,470 (issued to Cohen and Boyer), the disclosure of which is incorporated herein by reference], followed by culturing transformants in a nutrient broth.

Second, a DNA molecule of the present invention encodes aforementioned polypeptide. Thus, any of the degenerate set of codons encoding an instant polypeptide is contemplated. A particularly preferred coding sequence is the 1954 b.p. sequence set forth in SEQ ID No. 2, which has now been discovered to be a nucleotide sequence that encodes a polypeptide capable of binding imidazoline compound(s). In another embodiment, a DNA molecule

includes the 3318 b.p. nucleotide sequence shown in SEQ ID No. 3. This latter sequence is the entire EST04033 insert. It includes the nucleotide sequence of SEQ ID No. 2 which was predicted to have been translated into protein in the transfection experiments.

In another embodiment of the invention, a DNA molecule contains a nucleic acid sequence encoding the amino acid sequence (390 residues) shown in SEQ ID No. 6. This amino acid sequence corresponds to that derived from direct sequencing of the 5A-1 clone and represents a fragment of the native protein. The 5A-1 DNA molecule is defined by the 1171 b.p. nucleic acid sequence shown in SEQ ID No. 4.

A DNA molecule of the present invention can be synthesized according to the phosphotriester method [Matteucci et al., JACS, 103: 3185 (1988)]. This method is particularly suitable when it is desired to effect site-directed mutagenesis of an instant DNA sequence, whereby a desired nucleotide substitution can be readily made. Another method for making an instant DNA molecule is by simply growing cells transformed with plasmids containing the DNA sequence, lysing the cells, and isolating the plasmid DNA molecules. Preferably, an isolated DNA molecule of the invention is made by employing the polymerase chain reaction (PCR) [e.g., U.S. Patent No. 4,683,202 (issued to Mullis)] using synthetic primers that anneal to the desired DNA sequence, whereby DNA molecules containing the desired nucleotide sequence are amplified. Also, a combination of the above methods can be

employed, such as one in which synthetic DNA is ligated to CDNA to produce a quasi-synthetic gene [e.g., U.S. Patent No. 4,601,980 (issued to Goeddel et al.)].

A further aspect of the invention is for a vector, e.g., a plasmid, that contains at least one of the nucleotide sequences shown in SEQ ID Nos. 1-4 or those predicted by the genomic clone in SEQ ID No. 21. Whenever the reading frame of the vector is appropriately selected, the vector encodes an IR polypeptide of the invention. Hence, as well as full-length protein, fragments of the native IR protein are contemplated; as well as fusion proteins that incorporate an amino acid sequence as described herein. Also, a vector containing a nucleotide sequence having a high degree of homology with any of SEQ ID Nos. 1-4 or 21 is contemplated within the invention, particularly when it encodes a protein having imidazoline binding activity.

A recombinant vector of the invention can be formed by ligating an afore-mentioned DNA molecule to a preselected expression plasmid, e.g., with T4 DNA ligase. Preferably, the plasmid and DNA molecule are provided with cohesive (overlapping) terminii, with the plasmid and DNA molecule operatively linked (i.e., in the correct reading frame).

Another aspect of the invention is a host cell transfected with a vector of the invention. Relatedly, a protein expressed by a host cell transfected with such a vector is contemplated, which protein may be bound to the cell membrane. Such a protein can be identical with an aforementioned polypeptide, or it can be

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a fragment thereof, such as when the polypeptide has been partially digested by a protease in the cell. Also, the expressed protein can differ from an aforementioned polypeptide, as whenever it has been subjected to one or more post-translational modifications. For the protein to be useful within the context of the present invention, it should exhibit imidazoline binding capacity.

A method of producing an imidazoline receptor protein is another aspect of the invention, which entails transfecting a host cell with an aforementioned vector, and culturing the transfected host cell in a culture medium to generate the imidazoline receptor. The receptor molecule can undergo any post-translational modification(s), including proteolytic decomposition, whereby its structure is altered from the basic amino acid residue sequence encoded by the vector. A suitable transfection method is electroporation, and the like.

With respect to transfecting a host cell with a vector of the invention, it is contemplated that a vector encoding an instant polypeptide can be transfected directly in animals. For instance, embryonic stem cells can be transfected, and the cells can be manipulated in embryos to produce transgenic animals. Methods for performing such an operation have been previously described [Bond et al., Nature, 374:272-276 (1995)]. These methods for expressing an instant CDNA molecule in either tissue culture cells or in animals can be especially useful for drug discovery.

Possibly the most significant aspect of the present invention is in its potential for affording a method of screening for a ligand (drug) that binds to an imidazoline receptor. Such a method comprises culturing an above-mentioned host cell in a culture medium to express an instant imidazoline receptive polypeptide, then contacting the polypeptides with a labelled ligand, e.g., radiolabelled p-iodoclonidine, for the imidazoline receptor under conditions effective to bind the labelled ligand thereto. The polypeptides are further contacted with a candidate ligand, and any displacement of the labelled ligand from the polypeptides is detected. Displacement signifies that the candidate ligand actually binds to the imidazoline receptor. These steps could be performed on intact host cells, or on proteins isolated from the cell membranes of the host cells.

Typically, a suitable drug screening protocol involves preparing cells (or possibly tissues from transgenic animals) that express an instant imidazoline receptive polypeptide. In this process, categories of chemical structure are systematically screened for binding affinity or activation of the receptor molecule encoded by the transfected CDNA. This process is currently referred to as combinatorial chemistry. With respect to the imidazoline receptor, a number of commercially available radioligands, e.g., ^{125}PIC, can be used for competitive drug binding affinity screening.

An alternative approach is to screen for drugs that elicit or block a second messenger effect known to be coupled to

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activation of the imidazoline receptor, e.g., moxonidine-stimulated arachidonic acid release. Even with a weak binding affinity or activation by one category of chemicals, systematic variations of that chemical structure can be studied and a preferred compound (drug) can be deduced as being a good pharmaceutical candidate. Identification of this compound would lead to animal testing and upwards to human trials. However, the initial rationale for drug discovery becomes vastly improved with an instant cloned imidazoline receptor.

Along these lines, a drug screening method is contemplated in which a host cell of the invention is cultured in a culture medium to express an instant imidazoline receptive polypeptide. Intact cells are then exposed to an identified agent (ie., agonist, inverse agonist, or antagonist) under conditions effective to elicit a second messenger or other detectable responses upon interacting with the receptor molecule. The imidazoline receptive polypeptides are then contacted with one or more candidate chemical compounds (drugs), and any modification in a second messenger response is detected. Compounds that mimic an identified agonist would be agonist candidates, and those producing the opposite response would be inverse agonist candidates. Those compounds that block the effects of a known agonist would be antagonist candidates for an <u>in vivo</u> imidazoline receptor. For meaningful results, the contacting step with a candidate compound is preferably conducted at a plurality of candidate compound concentrations.

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A method of probing for another gene encoding an imidazoline receptor or homologous protein is further contemplated. Such a method comprises providing a radiolabelled DNA molecule identical or complementary to one of the above-described CDNA molecules (probe). The probe is then placed in contact with genetic material suspected of containing a gene encoding an imidazoline receptor or encoding a homologous protein, under stringent hybridization conditions (e.g., a high stringency wash condition is 0.1 x SSC, 0.5% SDS at 65°C), and identifying any portion of the genetic material that hybridizes to the DNA molecule.

Still further, a method of selectively producing antibodies, (e.g., monoclonal antibodies, immunoreactive with an instant imidazoline-receptive protein) comprises injecting a mammal with an aforementioned polypeptide, and isolating the antibodies produced by the mammal. This aspect is discussed in more detail in an example presented hereinafter.

The present inventors began their search for a human imidazoline receptor CDNA by screening a λgt11 phage human hippocampus CDNA expression library. Their research had indicated that both of the known antisera (Reis and Dontenwill) that are directed against human imidazoline receptors were immunoreactive with identical bands on SDS gels of membranes prepared from the human hippocampus (an in other tissues). By contrast, other brain regions either were commercially unavailable as cDNA expression libraries or yielded inconsistencies between the two antisera. Therefore, it was felt

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that a human hippocampal cDNA library held the best opportunity for obtaining a CDNA for an imidazoline receptor. Immunoexpression screening was chosen over other cloning strategies because of its sensitivity when coupled with the ECL detection system used by the present inventors, as discussed hereinbelow.

A number of unique discoveries led to identifying the first 5A-1 clone as an imidazoline receptor CDNA. These included discoveries that led to the choice of a hippocampal CDNA library and adapting ECL to the antisera. Once the initial clone (5A-1) was identified and sequenced, a more complete clone (EST04033) was purchased without restriction from ATCC Inc. (Catalogue # 82815; American Type Culture Collection, Rockville, MD). EST 04033 was the only EST clone available at the time of the discovery of 5A-1, that contained a segment of complete homology (the origination of EST04033 is discussed later on). The binding affinities of the expressed protein after transfection in COS cells were determined by radioligand binding procedures developed in the inventor's laboratory [Piletz and Sletten, 1993, ibid].

To identify an instant CDNA clone encoding an imidazoline receptor it was preferable to employ both of the known antibodies to imidazoline receptors. These antibodies were obtained by contacting Dr. D. Reis (Cornell University Medical Center, New York City), and Drs. M. Dontenwill and P. Bousquet (Laboratoire de Pharmacologie Cardiovascular et Renale, CNRS, Strasbourg, France). These antisera were obtained free of charge and without

confidentiality or restrictions on their use. The former antiserum (Reis antiserum) was derived from a published imidazoline receptor protein [Wang et al., (1992, 1993), the disclosures of which are incorporated herein by reference]. The method for raising the latter antiserum (Dontenwill antiserum) has also been published [Bennai et al., (1995), the disclosure of which is also incorporated herein by reference]. The latter antiserum was developed using an anti-idiotypic approach that identified the pharmacologically correct (clonidine and idazoxan selective) binding site structure.

Example 1. Selectivity of the Antisera.

The obtained Reis antiserum had been prepared against a purified imidazoline binding protein isolated from BAC cells, which protein runs in denaturing-SDS gels at 70 Kda [Wang et al., 1992, 1993]. The Dontenwill antiserum is anti-idiotypic, and thus is believed to detect the molecular configuration of an imidazoline binding site domain in any species. Prior to being used for screening plaques, both antisera were cleaned by stripping out possible antibacterial antibodies.

Both antisera have been tested to ensure that they are in fact selective for a human imidazoline receptor. In particular, we found that both of these antisera detected identical bands in human platelets and hippocampus, and in brainstem RVLM (NRL) by Western blotting (see Fig. 1). In these studies, in order to increase sensitivity over previously published detection methods,

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an ECL (Enhanced Chemiluminescence) system was employed. The linearity of response of the ECL system was demonstrated with a standard curve. ECL detection was demonstrated to be very quantifiable and about ten times more sensitive than other screening methods previously used with these antisera. Western blots with antiserum dilutions of 1:3000 revealed immunoreactivity with as little as 1 ng of protein from a human hippocampal homogenate by dot blot analysis.

For the studies depicted in Fig. 1, human hippocampal homogenate (30μg) and NRL membrane proteins (10μg) were electrophoresed through a 12.5% SDS-polyacrylamide gel, electrotransfered to nitrocellulose and sequentially incubated with (1) the Reis antibody (1:2000 dilution) and (2) the Dontenwill antibody (1:5000 dilution). Immunoreactive bands were visualized with an Enhanced Chemiluminescence (ECL) detection kit (Amersham) using anti-rabbit Ig-HRP conjugated antibody at a dilution of 1:3000 and the ECL detection reagents. Following detection with the antibody, blots were stripped and reprocessed omitting the primary antibody to check for complete removal of this antibody. In panels A and B, lane 1 shows the immunoreactive bands observed with the Reis antibody and lane 2 shows the bands detected with the Dontenwill antibody. Protein molecular weight standards are indicated to the left of each panel (in Kda).

Despite the diverse origins of the Reis and Dontenwill antisera, both of these antisera detected a similar 85 Kda

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protein in human brain and other tissues. But, a 33 Kda band was found in human platelets. Although the 33 Kda band is of smaller size than that reported for other tissues [Wang et al., 1993; Escriba et al., 1994; Greney et al., 1994], the fact that both antisera detected it, suggests that both the 85 Kda and 33 Kda bands may be imidazoline binding polypeptides. The 85 and 33 Kda bands were enriched in plasma membrane fractions, as is known to be the case for IR_1 binding, but not I_2 binding [Piletz and Sletten, 1993].

A significant positive correlation was established for the 85 Kda band detected by the Dontenwill antiserum with IR_1 Bmax values across nine rat tissues ($r^2 = 0.8736$). A similar positive correlation was established amongst platelet samples from 15 healthy platelet donors between radioligand IR_1 Bmax values (but not I_2 or α_2AR Bmax values), and the 33 Kda band (presumed IR_1 immunoreactivity) on Western blots. This correlation exhibited a slope factor close to unity (results not shown). These correlations strongly suggested that an IR_1 binding protein might be revealed in an imidazoline receptor-antibody Western blotting assay. Furthermore, the Reis antiserum failed to detect authentic α_2AR, MAO A, or MAO B bands on gels, i.e., it was not immunoreactive with MAO at MW = 61 Kda, or α_2AR at MW = 64 Kda. Additionally, no immunoreactive bands were observed using preimmune antiserum. Thus, after extensively characterizing these antisera with human and rat materials, it was concluded that these antisera are indeed selective for human

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imidazoline receptor protein.

Example 2. Cloning of cDNA For An Imidazoline Receptor

A commercially available human hippocampal cDNA λgt11 expression library (Clontech Inc., Palo Alto, CA) was screened for immunoreactivity sequentially using both the anti-idiotypic Dontenwill antiserum and the Reis antiserum. Standard techniques to induce protein and transference to a nitrocellulose overlay were employed. [See, for instance, Sambrook et al., 1989, "Molecular Cloning: A Laboratory Manual," Cold Spring Harbor Laboratory Press]. After washing and blocking with 5% milk, the Dontenwill antiserum was added to the overlay at 1:20,000 dilution in Tris-buffered saline, 0.05% Tween20, and 5% milk. The Reis antiserum was employed similarly, but at 1:15,000 dilution. These high dilutions of primary antiserum were chosen to avoid false positives. The secondary antibody was added, and positive plaques were identified using ECL. Representative results are shown in Fig. 2.

Positive plaques were pulled and rescreened until tertiary screenings yielded only positive plaques. Four separate positive plaques were identified from more than 300,000 primary plaques in our library. Recombinant λgt11 DNA purified from each of the four plaques was subsequently subcloned into E. coli pBluescript vector (Stratagene, La Jolla, CA). Sequencing of these four cDNA inserts in pBluescript demonstrated that they were identical, suggesting that only one cDNA had actually been identified four

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times. Thus, the screening had been verified as being highly reproducible and the frequency of occurrence was as expected for a single copy gene, i.e., one in 75,000 transcripts. As shown in Fig. 2, the protein produced by the first positive clone, designated 5A-1, tested positive with both the Reis antiserum and the Dontenwill antiserum. Clone 5A-1 has been deposited under the Budapest Treaty with the American Type Culture Collection (ATCC), 12301 Parklawn Drive, Rockville, MD, USA, 20852, on August 28, 1997 and has been assigned deposit accession no. ATCC 209217. Tertiary-screened plaques of 5A-1 were all immuno-positive with either of the two known anti-imidazoline receptor antisera, but not with either preimmune antisera. These results suggested that clone 5A-1 encoded a fusion peptide similar to or identical with one of the predominant bands detected in human Western blots by both the Dontenwill and Reis antisera.

Sequencing of the first four clones was performed by contracting with ACGT Company (Chicago, IL) after subcloning them into pBluescript vector SK (Stratagene). Both manual and automatic sequencing strategies were employed which are outlined as follows:

Manual Sequencing

1. DNA sequencing was performed using T7 DNA polymerase and the dideoxy nucleotide termination reaction.

2. The primer walking method [Sambrook et al., ibid.] was used in both directions.

3. (^{35}S)dATP was used for labelling.

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4. The reactions were analyzed on 6% polyacrylamide wedge or non-wedge gels containing 8 M urea, with samples being loaded in the order of A C G T.

5. DNA sequences were analyzed by MacVector Version 5.0. and by various Internet-available programs, i.e., the BLAST program.

Automatic Sequencing

1. DNA sequencing was performed by the fluorescent dye terminator labelling method using AmpliTaq DNA polymerase (Applied Biosystems Inc., Prizm DNA Sequencing Kit, Perkin-Elmer Corp., Foster City, CA).

2. The primer walking method was used. The primers actually used were a subset of those shown in SEQ ID Nos. 7-20.

3. Sequencing reactions were analyzed on an Applied Biosystems, Inc. (Foster City, CA) sequence analyzer.

These results demonstrated that the initial clone (5A-1) contained a 1171 base pair insert (see SEQ ID No. 4). The entire 5A-1 cDNA was found to exist as extended open reading frame for translation into protein. Consequently, it was determined that the 5A-1 cDNA must be a fragment of a larger mRNA.

cDNA Sequence Homologies

Using programs and databases available on the Internet (retrieved from NCBI Blast E-mail Server address blast@ncbi.nlm.nih.gov), it was determined that the 5A-1 clone encodes a previously undefined unique molecule. The BLASTP

program [1.4.8MP, 20-June-1995 (build 11/13/95)] was used to compare all of the possible frames of amino acid sequences encoded by 5A-1 versus all known amino acid sequences available within multiple international databases [Altschul et al., J. Mol. Biol., 215: 403-410 (1990)]. Only one protein, from *Micrococcus luteus*, possessed a marginally significant homology ($p=0.04$)(41%) over a short stretch of 75 of the 390 amino acids encoded by 5A-1. Otherwise, there were not any amino acid homologies (i.e., with $p \leq 0.05$) for any known proteins. Therefore, the protein encoded by 5A-1 is not significantly related to MAO A or B, α_2AR, or any other known eukaryotic protein in the literature.

In contrast to the amino acid search on BLASTP, two nearly homologous EST cDNA sequences of undefined nature covering 155 and 250 b.p. of the 5A-1 clone were reported to exist using BLASTN (reached from the same Internet server on 11/13/95). BLASTN is a program used to compare known DNA sequences from international databases, regardless of whether they encode a polypeptide. Neither of the two EST cDNA sequences having high homology to 5A-1, to our knowledge have been reported anywhere else except on the Internet. Both were derived as Expressed Sequence Tags (ESTs) in random attempts to sequence the human cDNA repertoire [as described in Adams et al., Science, 252: 1651-1656 (1991)]. As far as can be determined, the people who generated these ESTs lack any knowledge of what protein(s) they encode. One cDNA, designated HSA09H122, contained 250 b.p. with 7 unknown/incorrect base pairs (97% homology) versus 5A-1 over

the same region. HSA09H122 was generated in France (Genethon, B.P. 60, 91002 Evry Cedex France) from a human lymphoblast cDNA library. The other EST, designated EST04033, contained 155 b.p. with 12 unknown/incorrect base pairs (92% homology) versus 5A-1 over the same region. EST04033 was generated at the Institute for Genomic Research (Gaithersburg, MD) from a human fetal brain cDNA clone (HFBDP28). Thus, both of these ESTs are short DNA sequences and contain a number of errors (typical of single-stranded sequencing procedures as used when randomly screening ESTs).

Based on the BLASTN search, the owner of HSA09H122 was contacted in an effort to obtain that clone. The current owner of the clone appears to be Dr. Charles Auffret (Paul Brousse Hospital, Genetique, B.P. 8, 94801 Villejuif Cedex, France). Dr. Auffret indicated by telephone that his clone came from a lot of clones believed to be contaminated with yeast DNA, and he did not trust it for release. Contamination with yeast DNA of that clone was later confirmed to have been reported within an Internet database. Thus, HSA09H122 was not reliable.

The other partial clone (EST04033) was purchased from American Type Culture Collection in Rockville, MD (ATCC Catalog no. 82815). A telephone call to the Institute for Genomic Research revealed that it had been deposited at ATCC under [insert terms]. As far as can be determined, the present inventors were the first to completely sequence EST04033. The complete size of EST04033 was 3389 b.p. (SEQ ID No. 1), with a

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3,318 b.p. nonplasmid insert (see SEQ ID No. 3). Within this sequence of EST04033 the remaining 783 base pairs of the coding sequence presumed for a 70 kDa imidazoline receptor were predicted at the 5′ side of 5A-1 (i.e., 783 coding nucleotides unique to EST04033 + 1171 coding nucleotides of 5A-1 = 1954 predicted total coding nucleotides; assuming b.p.# 1397-1400 in SEQ. No. 1 encodes the initiating methionine). The entire 1954 b.p. coding region for an ≈ 70 kDa protein is shown in SEQ ID No. 2. The nucleotide sequence of EST04033 was determined in the same manner as described previously for the 5A-1 clone. The nucleotide sequence of the entire clone is shown in SEQ ID No. 1. In this sequence, an identical overlap was observed for the sequence obtained previously for the 5A-1 clone and the sequence obtained for EST04033. The 5A-1 overlap began at EST04033 b.p. 2,181 (SEQ. No.1) and continued to the end of the molecule (b.p. 3,351).

Conclusions About Our cDNA Clones

cDNA of the present invention encode a protein that is immunoreactive with both of the known selective antisera for an imidazoline receptor, i.e., Reis antiserum and Dontenwill antiserum. Thus, an instant cDNA molecule produces a protein immunologically related to a purified imidazoline receptor and has the antigenic specificity expected for an imidazoline binding site. These antisera have been documented in the scientific literature as being selective for an "imidazoline receptor",

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which provides strong evidence that such an imidazoline receptor has indeed been cloned.

As mentioned, our instant cDNA sequence contains open reading frame distinct from any previously described proteins. Therefore, the encoded protein is novel, and it is unrelated to α_2-adrenoceptors or monoamine oxidases. Small hydrophobic domains in the predicted amino acid sequence suggest that the protein is probably membrane bound, as expected for an imidazoline receptor.

Example 3. Cloning of a Human Gene

A pre-made genomic library of human placental DNA was purchased from Stratagene (La Jolla, CA) to screen for an IR gene by hybridization. The genomic library was constructed in Stratagene's vector λ FIX® II (catalog # 946206), and it was grown in XL1-Blue MRA (P2) host bacteria. It was titered to yield approximately 50,000 plaques per 137 mm plate. Lifts from six such plates were screened in duplicate by hybridization. The DNA probe used for screening was a 1.85 kb EcoR1 fragment from EST 04033 cDNA (uniquely related to our sequences based on the BLASTN). After the restriction digestion of EST 04033 DNA, the 1.85 kb fragment was extracted from an agarose electrophoresis gel, cleaned according to the GENECLEAN® III kit manual (BIO 101, Inc., P.O. Box 2284, La Jolla, CA), and radiolabeled with [α-^{32}P]d-CTP according to Stratagene's Prime-It® II Random Primer Labeling Kit manual. Plaques were lifted onto

137 mm Duralon-UV™ membranes (Stratagene's catalog #420102), denatured, and cross-linked with Stratgene's UV-Stratalinker™ 1800. Hybridization was conducted under high stringency conditions: prehybridization = 6 X SSC, 1 % SDS, 50 % formamide, and 100 1μg/ml of sheared, denatured salmon sperm DNA at 42°C for 2 hrs; hybridization = 6 X SSC, 1 % SDS, 50 % formamide, and 100 μg/ml of sheared, denatured salmon sperm DNA at 45°C overnight; wash = 2 washes of 1 X SSC, 0.1 % SDS at 65°C and 3 washes of 0.2 X SSC, 0.2 % SDS at 65°C. This hybridization procedure is essentially described in Stratagene's vector λ FIX® II instruction manual. Positive plaques were localized by developing Kodak BioMax films. Two positive genomic clones of identical size were retained through three rounds of screening.

One of the positive genomic clones (designated JEP 1-A) was selected for complete characterization. It was found to contain an ≈ 17 kb insert. Large-scale preparations of this genomic clone DNA were performed using the λ QUICK! SPIN kit (BIO101, La Jolla, CA). To verify that we had cloned a gene corresponding to 5A-1 and EST04033 cDNA, some restriction site positions in the genomic clone were determined using the FLASH Nonradioactive Gene Mapping Kit (Stratagene) and compared to Southern blots of human DNA. The location of genomic sequences highly related to (or identical to) those of our cDNA clones was determined by high stringency hybridization (as above) with the following ^{32}P-labeled probe: a 1110 bp *Apa*I-*Eco*RI fragment from the cDNA clone 5A-1. This fragment was chosen as the probe because it lacks the GAG

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repeat (encoding glutamic acids), which might have complicated matters if it were found to be repeated elsewhere in the genome. With genomic clone JEP1-A, we detected a 14.1 kb *Eco*RI fragment and a 7.7 kb *Sac*I fragment that hybridized with this probe. Southern blots containing *Eco*RI- or *Sac*I-digested human genomic DNA (from human blood) with the 1110 bp *Apa*I-*Eco*RI cDNA probe also resulted in the detection of a 14.1 kb *Eco*RI fragment and a 7.7 kb *Sac*I fragment. No additional restriction fragments of human genomic DNA appeared to hybridize with this probe under lower stringency conditions. These results strongly suggested that this gene (JEP-1A) encodes transcript(s) giving rise to the 5A-1 and EST04033 cDNA clones. Clone JEP-1A has been deposited under the Budapest Treaty with the American Type Culture Collection (ATCC), 12301 Parklawn Drive, Rockville, MD, USA, 20852, on August 28, 1997 and has been assigned deposit accession no. ATCC 209216.

Genomic DNA sequencing was done by contract with Cadus Pharmaceutical Corporation (Tarrytown, NY). The original lambda JEP1-A clone was subcloned into pZero (Invitrogen) as a convenient vector. The initial fragments for sequencing were derived from Sac I and Xba I restriction enzymes. The short Sac I fragments of 1.5, 3.0 and 3.5 kb were further digested with Hind III, Pst I, and Kpn I yielding 15 subclones of varying length. The procedure consisted of sequencing all these subclones and parent clones with vector forward and reverse primers. Subsequently, this initial round of sequencing was

supplemented with primer walking using custom oligonucleotides. The Sac I fragments were joined together by primer walking using the 2 Xba I fragments of 3 and 10 Kb. Then, the largest Sac I fragment (8 kb) and the 10 kb Xba I fragment were used as templates for a transposon sequencing method. The method used was the Primer Island Transposition Kit (Perkin-Elmer Corp., Norwalk, CT; Applied Biosystems) (ABI). The kit consists of a synthetic transposon (Ty1) containing forward and reverse primers and the integrase enzyme which inserts the transposon randomly into the target plasmid DNA. Transposon insertion is an alternative to subcloning or primer walking when sequencing a large region of DNA (Devine and Boeke, Nucleic Acids Res. 22: 3765-3772 (1994); Devine et al., Genome Res., in press, (1997); Kimmel et al., In Genome Analysis, a Laboratory Manual, Cold Spring Harbor Press, NY, NY, in press (1997). A total of over 250 individual sequencing reactions were performed. Sequencing was done on ABI model 373 and 377 automated sequencers using ABI dye-terminator sequencing kits. Primers were designed using Gene Runner software (Hastings Software, Hastings On Hudson, NY). Oligonucleotides were purchased from Gibco-BRL (Gaithersburg, MD). Sequence assembly was performed using Sequencer Software (Gene Codes Corp., Ann Arbor, MI) from 4-fold redundancy of sequences.

The entire sequence of our JEP-1A genomic clone is shown in SEQ. 21. The computer program, GENSCAN 1.0, was able to identify splice sites of known topology. As expected, this gene contained

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a number of introns. See Table 1 hereinbelow. Only one continuous open reading frame was identified within our genomic clone. This open reading frame was interrupted by a number of introns (which is typical of eukaryotic transcripts) as shown in Fig. 5. The predicted polypeptide is encoded by the genomic DNA beginning at b.p. # 971 of SEQ ID No. 21. The predicted amino acid sequence of the polypeptide encoded thereby is shown in SEQ ID No. 22. As can be seen, the entire 5A-1 DNA and polypeptide sequence was encapsulated within this predicted genomic transcript. Therefore, there is no question that this is the gene encoding 5A-1 and EST04033 cDNA. In addition, JEP-1A has more nearly defined the full-length transcript (by at least 102 more coding nucleotides than the cDNAs alone).

TABLE 1

Position of Predicted Introns and Exons

GENSCAN 1.0 Date run: 26-Aug-97 Time: 12:35:39
Sequence gs_seqfile : 15202 bp : 58.36% C+G : Isochore 4 (57.00 - 100.00 C+G%)
Parameter matrix: HumanIso.smat
Predicted genes/exons:

Gn.Ex	Type	S	.Begin	...End	.Len	Fr	Ph	I/Ac	Do/T	CodRg	P..	Tscr..
1.01	Intr	+	971	1084	114	1	0	69	98	200	0.836	20.91
1.02	Intr	+	4096	4177	82	0	1	37	53	81	0.358	-0.13
1.03	Intr	+	5732	5856	125	0	2	117	95	84	0.953	13.48
1.04	Intr	+	6997	7046	50	0	2	95	116	44	0.998	6.52
1.05	Intr	+	8416	9825	1410	1	0	96	94	2914	0.970	283.09
1.06	Intr	+	10489	10897	409	1	1	15	59	318	0.517	17.19
1.07	Intr	+	11293	11449	157	0	1	57	61	236	0.998	18.57
1.08	Intr	+	11923	12051	129	2	0	84	63	224	0.997	21.34
1.09	Intr	+	12570	12731	162	1	0	95	80	229	0.996	23.94
1.10	Term	+	13090	13700	611	2	2	59	41	1012	0.942	89.44
1.11	PlyA	+	14257	14262	6							1.05

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A BLASTN analysis of the entire genomic sequence (on 08/26/97) demonstrated again that this gene has not been previously defined in the literature.

As with the cDNA clones, some EST sequences of identity were found (listed below and later). Of particular interest was a variance in the first intron splice site predicted by the computer. Upstream of that site (ie., upstream of amino acids PEKKGGE = amino acids predicted after first splice site) we have identified two types of transcripts. Genomic clone JEP-1A predicted 34 amino acids upstream of that sequence before entering another intron upstream. In an identical manner, three ESTs (H61282, AA428790 and AA428250) overlapped that entire region in our clones and they contained the identical nucleotides for those 34 amino acids, plus an additional 22 more amino acids further upstream. By comparison, however, our EST04033 varied from all of these ESTs upstream of that site. This means, the first 1,532 nucleotides of EST04033 (thought to encode translation of amino acids 1-56 of EST04033 beginning at b.p. 1,398 in SEQ. 1) are completely at variance with the other ESTs down to that splice site, but from there on they are identical. This provides strong evidence that this site can generate two alternatively spliced transcripts which can produce at least one functional protein (ie., the transfections with EST04033). For the reader's information, this splice site is upstream of b.p. # 1,565 in SEQ.1, b.p. # 168 in SEQ.2, b.p. # 1,532 in SEQ.3, amino acid # 57 in SEQ.5, and b.p. # 971 in the genomic SEQ.21.

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Genomic Sequence Analysis

Of interest is a unique glutamic- and aspartic acid-rich region within our predicted protein. This region of the IR protein delineates a highly unique span of 59 amino acids, 36 of which are Glu or Asp residues (61%). This region was largely discovered within clone 5A-1 and it is present within all discovered and predicted transcripts from the gene (EST04033 included) . This sequence lies between two potential transmembrane loops (hydrophobic domains). The identification of this unique Glu/Asp-rich domain within our clones is consistent with an expected negatively charged pocket capable of binding clonidine and agmatine, both of which are highly positively charged ligands. Also, since the Dontenwill antiserum was specifically developed against an idazoxan/clonidine binding site, and its immunoreactivity is directed against the clone 5A-1/λgt11 fusion protein, this suggests that clone 5A-1 might encode an imidazoline binding site. Furthermore, this glu/asp-rich sequence is located within the longest stretch of homology that the clone has with any known protein, i.e., the ryanodine receptor (as determined by on BLASTN). Specifically, we have discovered four regions of homology between the imidazoline receptor and the ryanodine receptor, which are all Glu/Asp-rich. The total nucleic acid homology is 67% with the ryanodine receptor DNA over the stretches encompassing this region. However, this is not sufficient to indicate that the imidazoline receptor is a subtype of the ryanodine receptor, because this

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homologous stretch is still a minor portion of the overall transcript(s) identified in the gene. Instead, this significant homology may reflect a commonality in function between this region of the IR and the ryanodine receptor.

The Glu/Asp-rich region within the ryanodine receptor has also been reported to define a calcium and ruthenium red dye binding domain that modulates the ryanodine receptor/Ca^{++} release channel located within the sarcoplasmic reticulum. The only other charged amino acids within the Glu/Asp-rich region of our clones are two arginines (the ryanodine receptor has uncharged amino acids at the corresponding positions).

Based on this identification of Arg residues within the Glu/Asp-rich region of the predicted imidazoline binding site, the assistance of Dr. Paul Ernsberger (Case Western Reserve University, Cleveland, Ohio) was enlisted. Dr. Ernsberger performed phenylglyoxal attack of arginine on native PC-12 membranes. Dr. Ernsberger was able to demonstrate that this treatment completely eliminated imidazoline binding sites in these membranes. This provides some indirect evidence that the native imidazoline binding site also contains an Arg residue. On the other hand, attempts to chemically modify cysteine and tyrosine residues, which are not located near the Glu/Asp-rich region did not affect PC-12 membrane binding of imidazolines.

As a further test of the sequence, it was determined whether native IR binding sites in PC-12 cells would be sensitive to ruthenium red. From the structure of the cloned sequence, it was

reasoned that native IR should bind ruthenium red. Accordingly, a competition of ruthenium red with ^{125}PIC at native IR sites on PC-12 membranes was studied. In these studies it was observed that ruthenium red competed for ^{125}PIC binding to the same extent as did the potent imidazoline compound, moxonidine, i.e., 100% competition. Furthermore, the IC_{50} for competition of ruthenium red at IR was slightly more robust than reported for ruthenium red on the activation of calcium-dependent cyclic nucleotide phosphodiesterase - the previous most potent effect of ruthenium red on any biological site - indicating possible pharmacological importance. It is also noteworthy that calcium failed to compete for ^{125}PIC binding at PC-12 IR sites (as did a calcium substitute, lanthanum). We and others have previously reported that a number of other cations robustly interfere with IR binding [Ernsberger et al., Annals NY Acad.Sci., 763: 22-42 (1995); Ernsberger et al., Annals NY Acad.Sci., 763: 163-168 (1995)]. Attempts were also made to directly stain the proteins in SDS gels with ruthenium red [Chen and MacLennan, J. Biol. Chem., 269: 22698-22704 (1994)]. It was found that ruthenium red stains the same platelet (33 kDa) and brain (85 kDa) bands that Reis antiserum detects. (Remember, the same 33 kDa band was verified to directly correlate with ^{125}PIC Bmax values for IR.) Thus, these results linked the attributes predicted from the cloned sequence to a native IR binding site.

Two other facets of the predicted polypeptide from JEP-1A suggest that we have identified most of the functional sequences.

First, our predicted protein is comparable in regard to both the order and size of three regions of importance to the function of the interleukin-2Rβ receptor (IL-2Rβ). Specifically, IL-2Rβ possesses the following regions over a span of 286 amino acids: ser-rich region, followed by glu/asp-rich region, followed by proline-rich region. Likewise, our predicted protein has the same three regions, in the same order, over a span of about 625 amino acids. This suggests that our protein might function similarly as cytokine receptors. Secondly, our predicted protein possesses a cytochrome p450 heme-iron ligand signature sequence [Nelson et al., Pharmacogenetics 6: 1-42 (1996)]. This suggests that our protein might also function as do cytochrome p450s in oxidative, peroxidative and reductive metabolism of endogenous compounds.

Some additional findings about the amino acid sequence of our instant IR polypeptide are: (1) The glu/asp-rich region also bears similarity to an amino acid sequence within a GTPase activator protein. (2) There appear to be four small hydrophobic domains indicative of transmembrane domain receptors. (3) A number of potential protein kinase C (PKC) phosphorylation sites appear near to the carboxy side of the protein, and we have previously found that treatment of membranes with PKC leads to an enhancement of native IR binding. Thus, these observations are all consistent with other observations expected for native IR.

RNA Studies

Northern blotting has also been performed on polyA$^+$ mRNA from human tissues in order to ascertain the regional expression of the mRNA corresponding to our cDNA. The same 1110 b.p. *Apa*I-*Eco*RI fragment from cDNA clone 5A-1 used in Southern blots was used for these studies. This probe region was not found within any other known sequences on the BLASTN database. The results revealed a 6 kb mRNA band, which predominated over a much fainter 9.5 kb mRNA in most regions (Fig. 6). Some exceptions to this pattern were in lymph nodes and cerebellum (Fig. 6), where the 9.5 kb band was equally or more intense. Although the 6 kb band is weakly detectable in some non-CNS tissues, it is enriched in brain. An enrichment of the 6 kb mRNA is observed in brainstem, although not exclusively. The regional distribution of the mRNA is somewhat in keeping with the reported distribution of IR binding sites, when extrapolated across species (Fig. 6). Thus, the rank order of Bmax values for IR in rat brain has been reported to be frontal cortex > hippocampus > medulla oblongata > cerebellum [Kamisaki et al., Brain Res., 514: 15-21 (1990)]. Therefore, with the exception of human cerebellum, which showed two mRNA bands, the distribution of the mRNA for our the present cloned cDNA is consistent with it belonging to IR.

[It should be noted that while IR binding sites are commonly considered to be low in cerebral cortex compared to brainstem, this is in fact a misinterpretation of the literature based only on comparisons to the alpha-2 adrenoceptor's Bmax, rather than on absolute values. Thus, IR Bmax values have actually been

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reported to be slightly higher in the cortex than the brainstem, but they only "appear" to be low in the cortex in comparison to the abundance of alpha-2 binding sites in cortex. Therefore, the distribution of the IR mRNA is reasonably in keeping with the actual Bmax values for radioligand binding to the receptor [Kamisaki et al., (1990)].

A final point to emphasize about the Northern blots is that they clearly demonstrate two high-stringency transcripts (Fig. 6). This is in keeping with the alternatively spliced EST cDNAs mentioned earlier. Thus, we suggest this may be the basis for both the 6 and 9.5 kb transcripts.

Summary of Genomic Sequence Results

The JEP-1A clone clearly contains most of the gene. Within it we have identified at least 3,776 nucleotides for transcript(s) (encoding 1,065 amino acids plus 587 b.p. of untranslated region down to the polyT$^+$ tail). This has been lengthened by at least 66 coding nucleotides upstream (22 amino acids) in comparison to overlapping ESTs. In addition to this, we are quite confident of the splice site for the two observed mRNA sizes. Most of the functional sequences are predicted to be encoded within our genomic clone.

A summary of the evidence that a gene encoding an imidazoline receptor protein has been cloned is summarized in Table 2 hereinbelow.

TABLE 2

Comparison of Protein Predicted From Our Clones with Properties of Native IR_1 and I_2 Sites

Imidazoline Receptor-like Clone	Authentic IR_1	Authentic I_2
Original λ phage fusion protein (from 5A-1) is immunoreactive with Dontenwill and Reis antibodies	Dontenwill-Ab activity (a)inhibits RVLM IR_1 binding (^{3}H-Clonidine), & (b) correlates with 85 kDa Western band. Reis-Ab activity correlates w platelet IR_1 Bmax (^{125}PIC binding)	Dontenwill & Reis Abs both inhibit brain I_2 sites (^{3}H-IDX).
Segment homologous to a GTPase-activator prot'n	Weak to moderate sensitivity to GTP	Not sensitive to GTP
Predicts ≥ 120,000 MW protein	85,000 MW immunoreactivity	59-61,000 MW photoaffinity
Predicts 1-4 hydrophobic domains	Enriched in plasma membranes	Enriched in mitochondria
Encodes Glu/Asp-rich (negatively charged) domain consistent with Ca^{++} and ruthenium red binding	• Binds (+)-charged imidazolines • Sensitive to divalent cations • Sensitive to ruthenium red	• Binds (+)-charged imidazolines • Not sensitive to divalent cations • Unknown sensitivity for Ruthen. red
Arginine is only positively charged amino acid near Glu/Asp domain	• Arg attack eliminates binding • Cys & Tyr attack w/o effect on binding	Unknown
Encodes PKC sites	PKC treatment enhances binding	Unknown
Human mRNA Distribution; F.Cortex > hippocampus > medulla	Rat IR_1 Bmax (^{125}PIC): F.Cortex > hippocampus > medulla	Rat I_2 Bmax (^{3}H-IDX): Medulla > F. Cortex
Transfected COS-7 cells expressed high affinity for moxonidine & p-iodoclonidine (PIC)	High affinity for moxonidine and PIC	Low affinity for moxonidine and PIC

Example 4. Transient Transfection Studies

COS-7 cells were transfected with a vector containing EST04033 cDNA, which was predicted based on sequence analysis to contain the glu/asp rich region thought to be important for ligand binding to the imidazoline receptor protein. The EST04033 cDNA was subcloned into pSVK3 (Pharmacia LKB Biotechnology, Piscataway, NJ) using standard techniques [Sambrook, supra], and transfected via the DEAE-dextran technique as previously described [Choudhary et al., Mol.Pharmacol., 42: 627-633 (1992); Choudhary et al., Mol.Pharmacol., 43: 557-561 (1993); Kohen et al., J.Neurochem., 66: 47-56 (1996)]. A restriction map of the EST04033 cDNA is shown in Fig. 3. The restriction enzymes Sal I and Xba I were used for subcloning into pSVK3.

Briefly stated, COS-7 cells were seeded at 3 x 10^6 cells/100 mm plate, grown overnight and exposed to 2 ml of DEAE-dextran/plasmid mixture. After a 10-15 min. exposure, 20 ml of complete medium (10% fetal calf serum; 5 μg/ml streptomycin; 100 units/ml penicillin, high glucose, Dulbeccos' modified Eagle's medium) containing 80 μM chloroquine was added and the incubation continued for 2.5 hr. at 37°C in a 5% CO_2 incubator. The mixture was then aspirated and 10 ml of complete medium containing 10% dimethyl sulfoxide was added with shaking for 150 seconds.

Following aspiration, 15 ml of complete medium with dialyzed serum was added and the incubation continued for an additional 65 hours. After this time period, the cells from 6 plates were harvested and membranes were prepared as previously described

[Ernsberger et al., Annals NY Acad. Sci., 763: 22-42 (1995), the disclosure of which is incorporated herein by reference]. Parent, untransfected COS-7 cells were prepared as a negative control. Some membranes were treated with and without PKC for 2 hrs prior to analysis, since previous studies had indicated that receptor phosphorylation could be beneficial to detect IR binding.

Transfected samples were also analyzed by Western blots. The protocol used for Western blot assay of transfected cells is as follows. Cell membranes were prepared in a special cocktail of protease inhibitors (1 mM EDTA, 0.1 mM EGTA, 1 mM phenylmethyl-sufonylfluoride, 10 mM ϵ-aminocaproic acid, 0.1 mM benzamide, 0.1 mM benzamide-HCl, 0.1 mM phenanthroline, 10 μg/ml pepstatin A, 5 mM iodoacetamide, 10 μg/ml antipain, 10 μg/ml trypsin-chymotrypsin inhibitor, 10 μg/ml leupeptin, and 1.67 μg/ml calpain inhibitor) in 0.25 M sucrose, 1 mM $MgCl_2$, 5 mM Tris, pH 7.4. Fifteen μg of total protein were denatured and separated by SDS gel electrophoresis. Gels were equilibrated and electrotransferred to nitrocellulose membranes. Blots were then blocked with 10% milk in Tris-buffered saline with 0.1% Tween-20 (TBST) during 60 min. of gentle rocking. Afterwards, blots were incubated in anti-imidazoline receptor antiserum (1:3000 dil.) for 2 hours. Following the primary antibody, blots were washed and incubated with horseradish peroxidase-conjugated anti-rabbit goat IgG (1:3000 dil.) for 1 hr. Blots were extensively washed and incubated for 1 min. in a 1:1 mix of Amersham ECL detection

solution. The blots were wrapped in cling-film (SARAN WRAP) and exposed to Hyperfilm-ECL (Amersham) for 2 minutes. Quantitation was based on densitometry using a standard curve of known amounts of protein containing BAC membranes or platelet membranes run in each gel.

One nM [^{125}I]p-iodoclonidine was employed in the radioligand binding competition assays, since at this low concentration this radioligand is selective for the IR site much more than for I_2 binding sites. The critical processes of membrane preparation of tissue culture cells and the radioligand binding assays of IR and I_2 have been reviewed by Piletz and colleagues [Ernsberger et al., Annals NY Acad Sci., 763: 510-519 (1995)]. Total binding (n = 12 per experiment) was determined in the absence of added competitive ligands and nonspecific binding was determined in the presence of 10^{-4} M moxonidine (n = 6 per experiment). Log normal competition curves were generated against unlabeled moxonidine, p-iodoclonidine, and (-) epinephrine. Each concentration of the competitors was determined in triplicate and the experiment was repeated thrice.

The protocol to fully characterize radioligand binding in the transfected cells entails the following. First, the presence of IR and/or I_2 binding sites are scanned over a range of protein concentrations using a single concentration of [^{125}I]-p-iodoclonidine (1.0nM) and ^{3}H-idazoxan (8nM), respectively. Then, rate of association binding experiments (under a 10 μM mask of NE to remove α_2AR interference) are performed to determine if the

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kinetic parameters are similar to those reported for native imidazoline receptors [Ernsberger et al. Annals NY Acad. Sci., 763: 163-168 (1995)]. Then, full Scatchard plots of [^{125}I]-p-iodoclonidine (2-20 nM if like IR) and ^{3}H-idazoxan (5-60 nM if like I_2) binding are conducted under a 10 μM mask of NE. Total NE (10 μM)-displaceable binding is ascertained as a control to rule out α_2-adrenergic binding. The Bmax and K_D parameters for the transfected cells are ascertained by computer modeling using the LIGAND program [McPherson, G., J.Pharmacol.Meth., 14: 213-228 (1985)] using 20 μM moxonidine to define IR nonspecific binding, or 20 μM cirazoline to define I_2 nonspecific binding.

The results of the transient transfection experiments of the imidazoline receptor vector into COS-7 cells are shown in Fig. 4. Competition binding experiments were performed using membrane preparations from these cells and ^{125}PIC was used to radiolabel IR sites. A mask of 10 μM norepinephrine was used to rule out any possible α_2AR binding in each assay even though parent COS-7 cells lacked any α_2AR sites. Moxonidine and p-iodoclondine (PIC) were the compounds tested for their affinity to the membranes of transfected cells. As can be seen, the affinities of these compounds in competition with ^{125}PIC were well within the high affinity (nM) range.

The following IC_{50} values and Hill slopes were obtained in this study: moxonidine, IC_{50} = 45.1 nM (Hill slope = 0.35 ± 0.04); p-iodoclonidine without PKC pretreatment of the membranes, IC_{50} = 2.3 nM (Hill slope = 0.42 ± 0.06); p-iodoclonidine with PKC

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pretreatment of the membranes, IC_{50} = 19.0 nM (Hill slope = 0.48 ± 0.08). Shallow Hill slopes for [^{125}I]p-iodoclonidine have been reported before in studies of the interaction of moxonidine and p-iodoclonidine with the human platelet IR_1 binding site [Piletz and Sletten, (1993)]. Epinephrine failed to displace any of the [^{125}I]p-iodoclonidine binding in the transfected cells, as expected since this is a nonadrenergic imidazoline receptor. Furthermore, in untransfected cells less than 5% of the amount of displaceable binding was observed as for the transfected cells - and this "noise" in the parent cells all appeared to be low affinity (data not shown). These results thus demonstrate the high affinities of two imidazoline compounds, p-iodoclonidine and moxonidine, for the portion of our cloned receptor encoded within EST04033. PKC pretreatment of the membranes had no effect in the transfected COS cells.

It was also observed that the level of the expressed protein, as measured by Western blotting of the transfected cells, was consistent with the level of IR binding that was detected. In other words, a protein band was uniquely detected in the transfected cells, and it was of a density consistent with the amount of radioligand binding. Hence, the present results are in keeping with those expected for an imidazoline receptor. In summary, these data provide direct evidence that the EST04033 clone encodes an imidazoline binding site having high affinities for moxonidine and p-iodoclonidine, which is expected for an IR protein.

Example 5. Stable Transfection Methods.

Stable transfections can be obtained by subcloning the imidazoline receptor cDNA into a suitable expression vector, e.g., pRc/CMV (Invitrogen, San Diego, CA), which can then be used to transform host cells, e.g. CHO and HEK-293 cells, using the Lipofectin reagent (Gibco/BRL, Gaithersburg, MD) according to the manufacturer's instructions. These two host cell lines can be used to increase the permanence of expression of an instant clone. The inventors have previously ascertained that parent CHO cells lack both alpha$_2$-adrenoceptor and IR binding sites [Piletz et al., J. Pharm.& Exper. Ther., 272: 581-587 (1995)], making them useful for these studies. Twenty-four hours after transfection, cells are split into culture dishes and grown in the presence of 600 μg/ml G418-supplemented complete medium (Gibco/BRL). The medium is changed every 3 days and clones surviving in G418 are isolated and expanded for further investigation.

Example 6. Direct Cloning of More Complete Gene and Other Homologous Human IR.

Direct probing of other human genomic and cDNA libraries can be performed by preparing labelled cDNA probes from different subcloned regions of our clone. Commercially available human DNA libraries can be used. Besides the cDNA and genomic libraries we have already screened, another genomic library is EMBL (Clontech), which integrates genomic fragments up to 22 kbp long.

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It is reasonable to expect that introns may exist within other human IR genes so that only by obtaining overlapping clones can the full-length genes be sequenced. A probe encompassing the 5' end of an instant cDNA is generally useful to obtain the gene promoter region. Clontech's Human PromoterFinder DNA Walking procedure provides a method for "walking" upstream or downstream from cloned sequences such as cDNAs into adjacent genomic DNA.

Example 7. Methods for Preparing Antibodies to Imidazoline Receptive Proteins.

An instant imidazoline receptive polypeptide can also be used to prepare antibodies immunoreactive therewith. Thus, synthetic peptides (based on deduced amino acid sequences from the DNA) can be generated and used as immunogens. Additionally, transfected cell lines or other manipulations of the DNA sequence of an instant imidazoline receptor can provide a source of purified imidazoline receptor peptides in sufficient quantities for immunization, which can lead to a source of selective antibodies having potential commercial value.

In addition, various kits for assaying imidazoline receptors can be developed that include either such antibodies or the purified imidazoline receptor protein. A purification protocol has already been published for the bovine imidazoline receptor in BAC cells [Wang et al, 1992] and an immunization protocol has also been published [Wang et al., 1993]. These same protocols can be utilized with little if any modification to afford

purified human IR protein from transfected cells and to yield selective antibodies thereto.

In order to obtain antibodies to a subject peptide, the peptide may be linked to a suitable soluble carrier to which antibodies are unlikely to be encountered in human serum. Illustrative carriers include bovine serum albumin, keyhole limpet hemocyanin, and the like. The conjugated peptide is injected into a mouse, or other suitable animal, where an immune response is elicited. Monoclonal antibodies can be obtained from hybridomas formed by fusing spleen cells harvested from the animal and myeloma cells [see, e.g., Kohler and Milstein, Nature, 256: 495-497 (1975)].

Once an antibody is prepared (either polyclonal or monoclonal), procedures are well established in the literature, using other proteins, to develop either RIA or ELISA assays [see, e.g., "Radioimmunoassay of Gut Regulatory Peptides; Methods in Laboratory Medicine," Vol. 2, chapters 1 and 2, Praeger Scientific Press, 1982]. In the case of RIA, the purified protein can also be radiolabelled and used as a radioactive antigen tracer.

Currently available methods to assay imidazoline receptors are unsuitable for routine clinical use, and therefore the development of an assay kit in this manner could have significant market appeal. Suitable assay techniques can employ polyclonal or monoclonal antibodies, as has been previously described [U.S. Patent No. 4,376,110 (issued to David et al.), the disclosure of

which is incorporated herein by reference].

Summary

In summary, we have identified unique DNA sequences that have properties expected of a gene and the cDNA transcript(s) of an imidazoline receptor. Prior to our first cloning the cDNA, only two sequences of EST cDNA were identified within public databases having similar nature. But, these were both partial and imprecise sequences - not identified at all with respect to any encoded protein. Indeed, one of them (HSA09H122) was reported to be contaminated. In our hands, the other EST 04033 clone was correctly sequenced for the first time (in its entirety = 3318 bp). Prior to this, even the size of EST 04033 was unknown. The present inventors also demonstrated that an imidazoline receptive site can be expressed in cells transfected with the EST 04033 cDNA clone, and this site has the proper potencies of an IR. We have deduced most of the complete cDNA encoding this protein.

The present invention has been described with reference to specific examples for purposes of clarity and explanation. Certain obvious modifications of the invention readily apparent to one skilled in the art can be practiced within the scope of the appended claims.